1 Hydraulic Modeling with EPA-NET

1.1 Introduction

EPA-NET is a computer program that performs hydraulics computations in pressure-pipe systems. Most of the problems in the preceding chapters can be solved or well approximated using EPA-NET.

The remainder of this chapter shows how to use EPA-NET by a series of representative examples. These examples are at best a subset of the capabilities of the program, but should be enough to get one started. The program requires some hydraulic insight to interpret the results as well as detect data entry or conceptualization errors – hence the practical hydraulics review in Chapters 2 and 3.

1.2 Installing EPA-NET

The QuickTime movie shows how to download and install EPA-NET onto your computer. EPA-NET will run fine on a laptop computer, and even a Macintosh that has a guest Windows OS (WM-Ware, Parallels, or BootCamp). There may also be native Macintosh versions available – search the Internet, be surprised what one can find.

EPA-NET can also be installed onto a flash-drive and run directly from the drive[1].

1.3 EPA-NET Modeling by Example: Examples 1 through 4

EPA-NET models are comprised of nodes, links,and reservoirs. Pumps are treated as special links (that add head). Valves are also treated as special links depending on the valve types. All models must have a reservoir (or storage tank).

1.3.1 Defaults

The program has certain defaults that should be set at the beginning of a simulation. The main defaults of importance are the head loss equations (Darcy-Weisbach, Hazen-Williams, or Chezy-Manning) and the units (CFS, LPS, etc.)

[1] A useful trick on a networked system — be sure you set up the flash drive to be writeable!

1.3.2 Example 1: Flow in a Single Pipe

The simplest model to consider is from an earlier exercise in this workbook.

> A 5-foot diameter, enamel coated, steel pipe carries 60°F water at a discharge of 295 cubic-feet per second (cfs). Using the Moody chart, estimate the head loss in a 10,000 foot length of this pipe.

In EPA-NET we will start the program, build a tank-pipe system and find the head loss in a 10,000 foot length of the pipe. The program will compute the friction factor for us (and we can check on the Moody chart if we wish).

The main trick in EPA-NET is going to be the friction coefficient, in the EPA-NET manual on page 30 and 31, the author indicates that the program expects a roughness coefficient based on the head loss equation. The units of the roughness coefficient for a steel pipe are 0.15×10^{-3} feet. On page 71 of the user manual the author states that roughness coefficients are in millifeet (millimeters) when the Darcy-Weisbach head loss model is used. So keeping that in mind we proceed with the example.

Figure 1 is a screen capture of the EPA-NET program after installing the program. The program starts as a blank slate and we will select a reservoir and a node from the tool bar at the top and place these onto the design canvas.

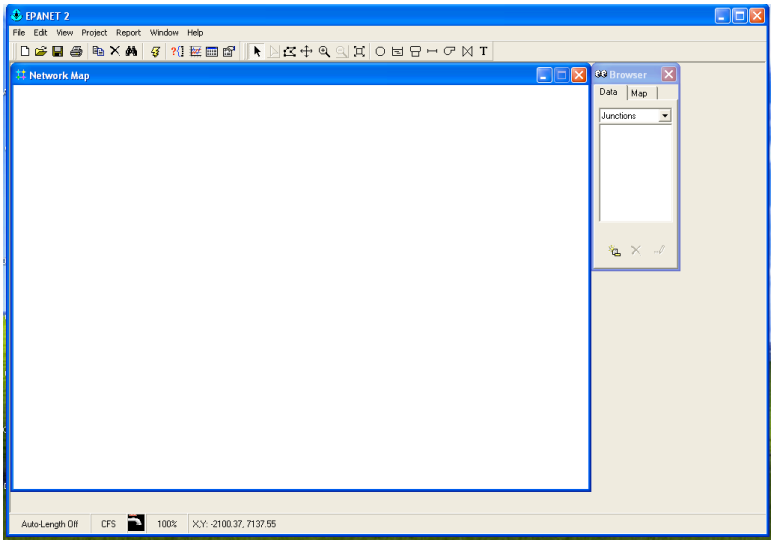

Figure 1: Start EPA-NET program

Figure 1 is a screen capture of the EPA-NET program after setting defaults for the simulation. Failure to set correct units for your problem are sometimes hard to detect (if the model runs), so best to make it a habit to set defaults for all new projects. Next we add the reservoir and

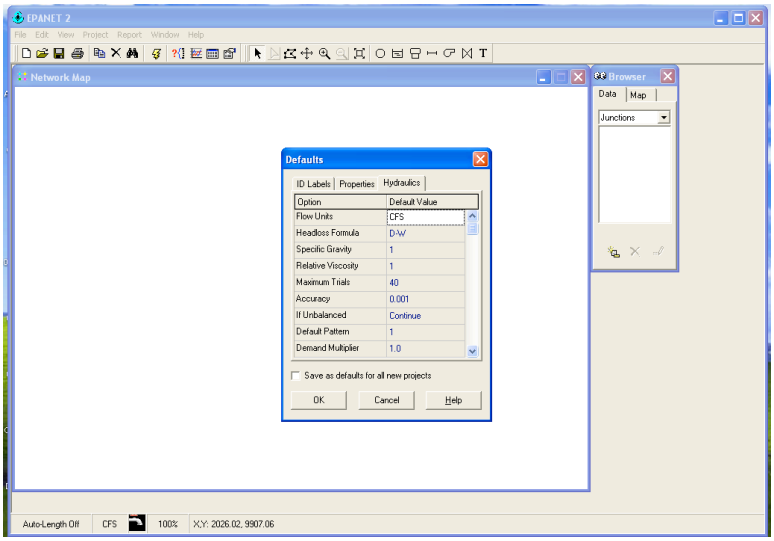

Figure 2: Set program defaults. In this case units are cubic-feet-per-second and loss model is Darcy-Weisbach.

the node. Figure 3 is a screen capture after the reservoir and node is placed. We will specify a total head at the reservoir (value is unimportant as long as it is big enough to overcome the head loss and not result in a negative pressure at the node. We will specify the demand at the node equal to the desired flow in the pipe. Next we will add the pipe.

Figure 4 is a screen capture after the pipe is placed. The sense of flow in this example is from reservoir to node, but if we had it backwards we could either accept a negative flow in the pipe, or right-click the pipe and reverse the start and end node connections.

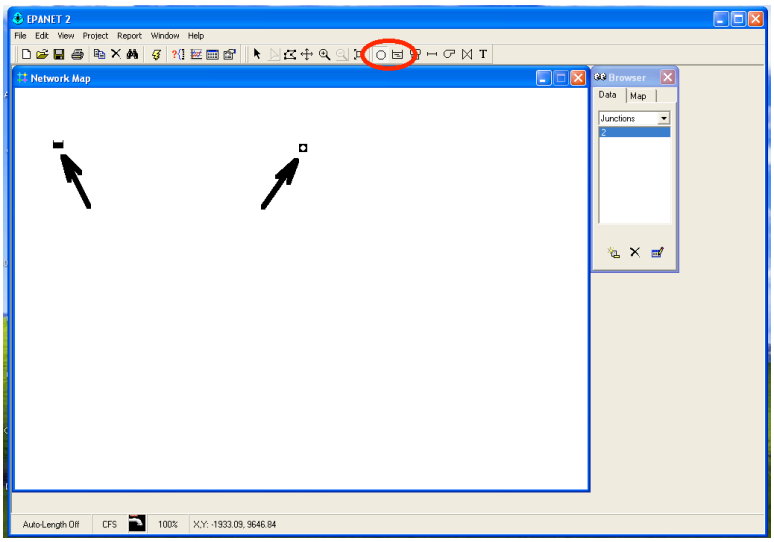

Figure 3: Place the reservoir and the demand node.

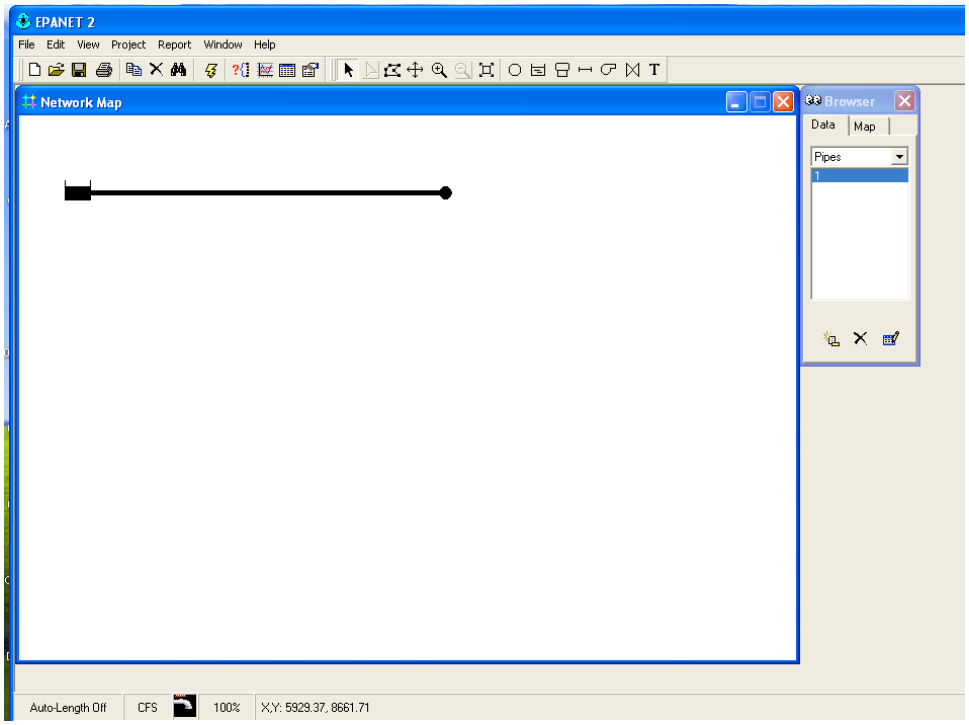

Figure 4: Link the reservoir and demand node with a pipe.

Now we can go back to each hydraulic element in the model and edit the properties. We supply pipe properties (diameter, length, roughness height) as in Figure 5.

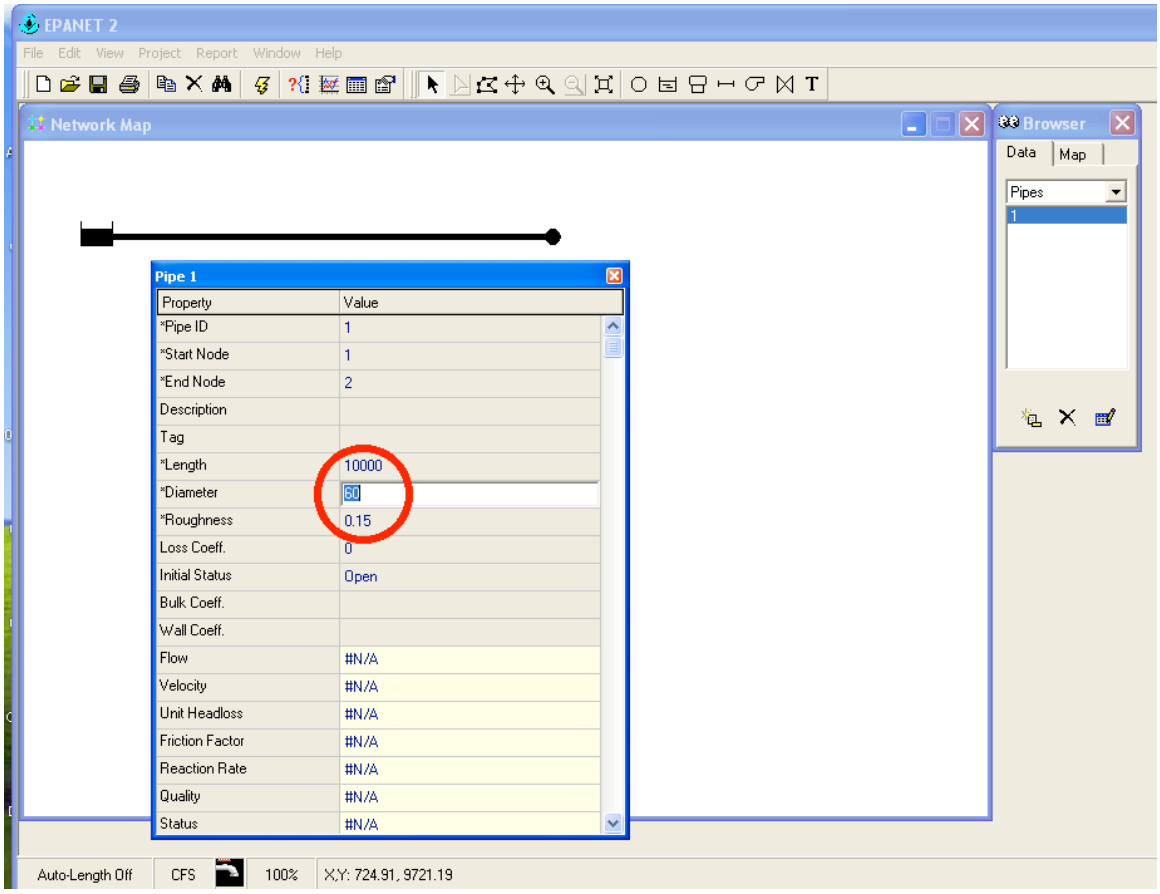

Figure 5: Set the pipe length, diameter, and roughness height.

We supply the reservoir total head as in Figure 6.

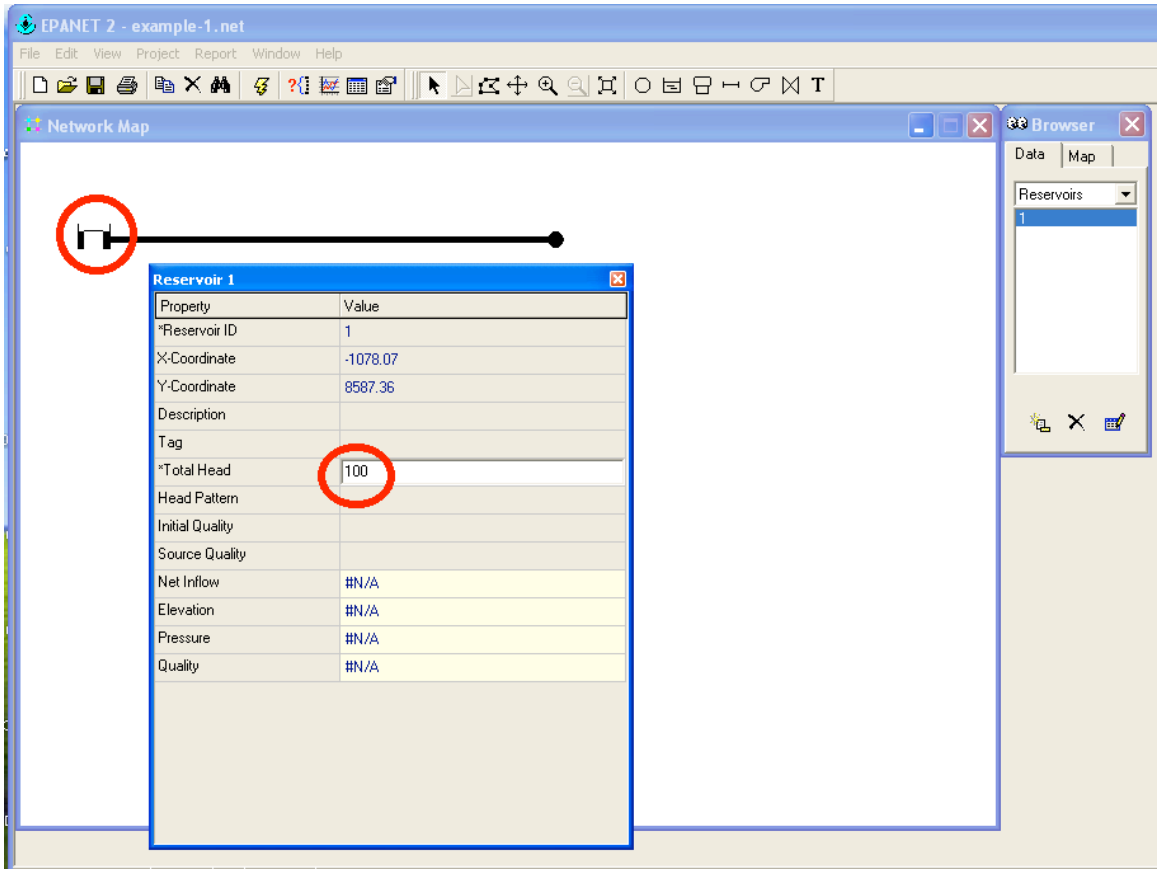

Figure 6: Set the reservoir total head, 100 feet should be enough in this example.

We set the demand node elevation and the actual desired flow rate as in Figure 7.

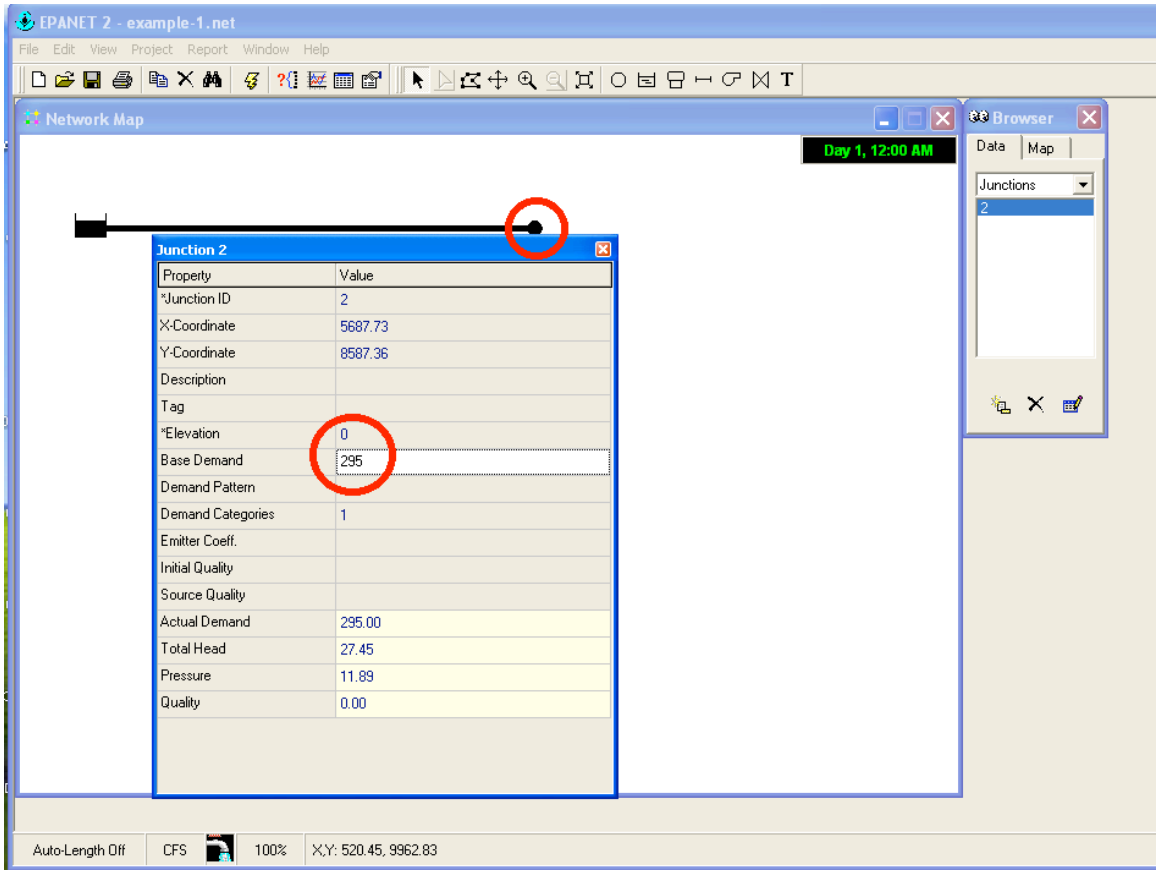

Figure 7: Set the node elevation and demand. In this case the elevation is set to zero (the datum) and the demand is set to 295 cfs as per the problem statement.

The program is now ready to run, next step would be to save the input file (File/Save/Name), thes run the program.

Run the program by selecting the lighting bolt looking thing (kind of channeling Zeus here) and the program will start. If the nodal connectivity is OK and there are no computed negative pressures the program will run. Figure 8 is the appearance of the program after the run is complete (the annotations are mine!). A successful run means the program found

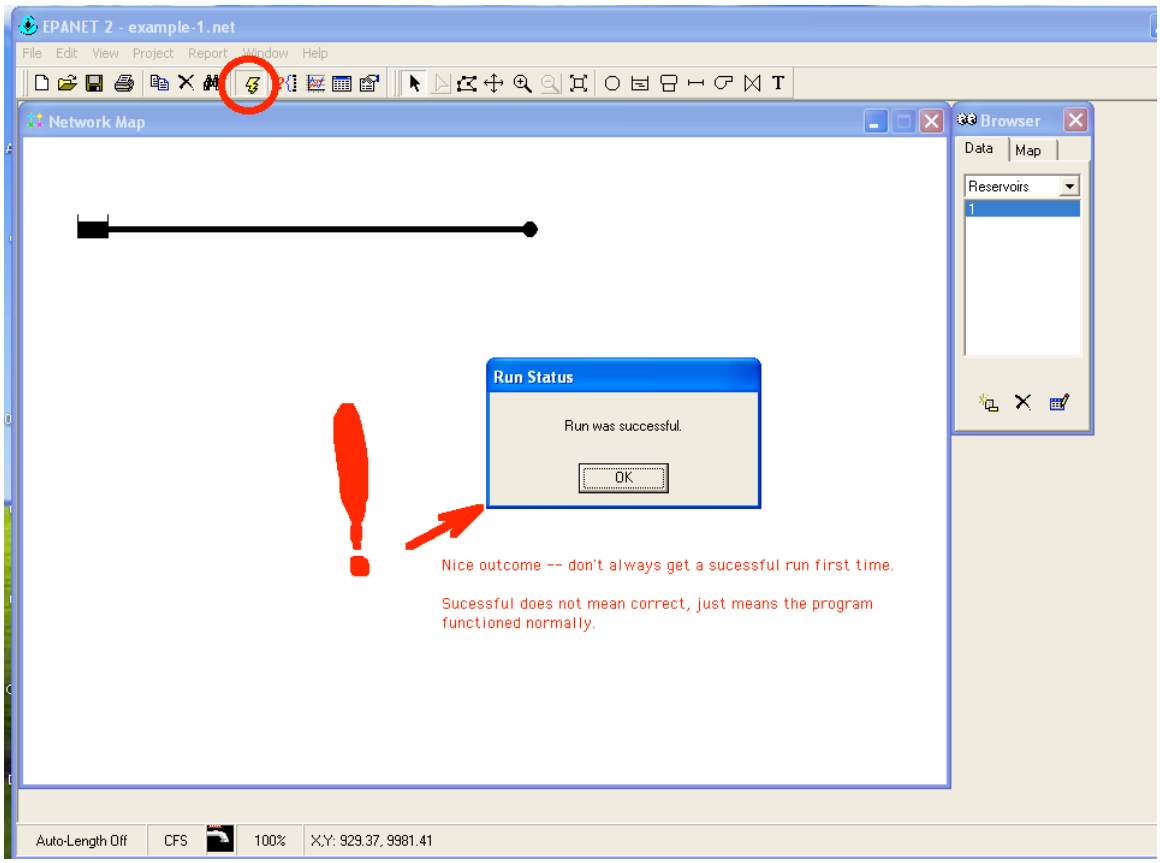

Figure 8: Running the program

an answer to the problem you provided – whether it is the correct answer to your problem requires the engineer to interpret results and decide if they make sense. The more common conceptualization errors are incorrect units and head loss equation for the supplied roughness values, missed connections, and forgetting demand somewhere. With practice these kind of errors are straightforward to detect. In the present example we select the pipe and the solution values are reported at the bottom of a dialog box.

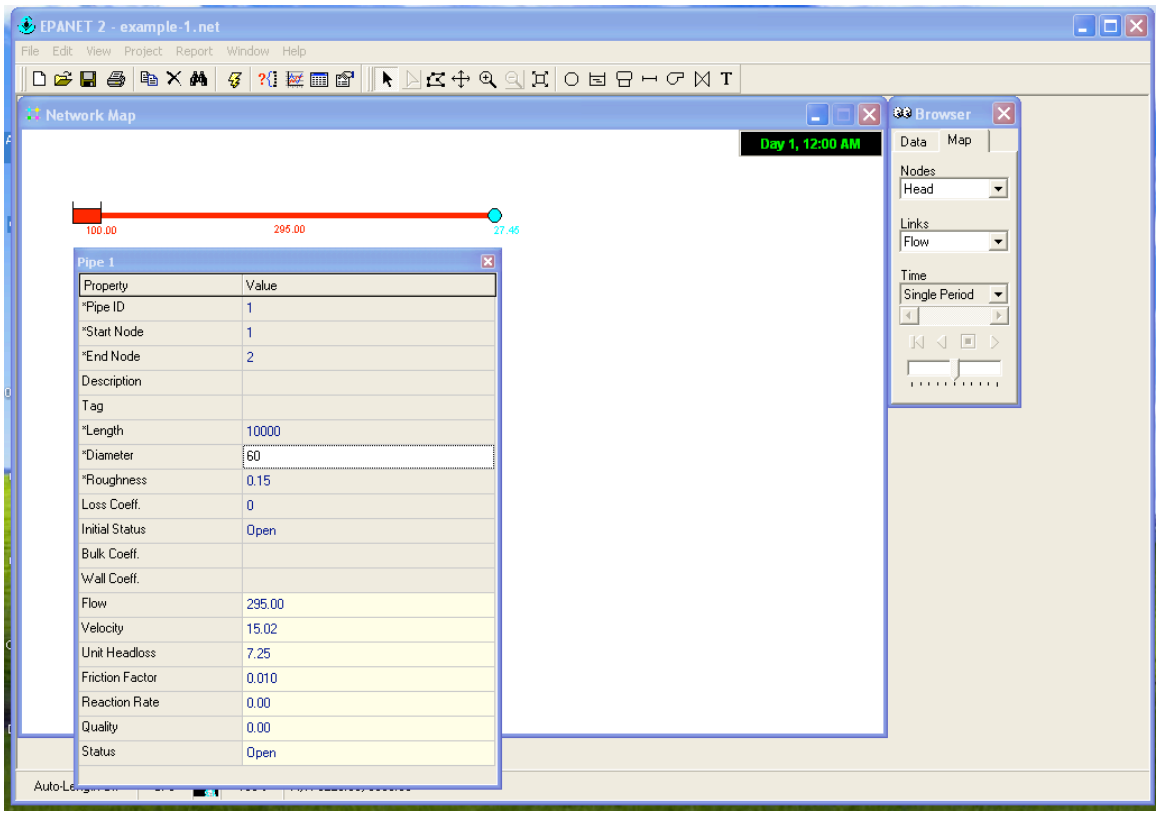

Figure 9: Solution dialog box for the pipe.

Figure 9 is the result of turning on the computed head values at the node (and reservoir) and the flow value for the pipe. The dialog box reports about 7.2 feet of head loss per 1000 feet of pipe for a total of 72 feet of head loss in the system. The total head at the demnad node is about 28 feet, so the head loss plus remaining head at the node is equal to the 100 feet of head at the reservoir, the anticipated result.

The computed friction factor is 0.010, which we could check against the Moody chart if we wished to adjust the model to agree with some other known friction factor.

1.3.3 Example 2: Flow Between Two Reservoirs

This example represents the situation where the total head is known at two points on a pipeline, and one wishes to determine the flow rate (or specify a flow rate and solve for a pipe diameter). Like the prior example it is contrived, but follows the same general modeling process.

As in the prior example, we will use EPA-NET to solve a problem we have already solved by hand.

> Using the Moody chart, and the energy equation, estimate the diameter of a cast-iron pipe needed to carry 60°F water at a discharge of 10 cubic-feet per second (cfs) between two reservoirs 2 miles apart. The elevation difference between the water surfaces in the two reservoirs is 20 feet.

As in the prior example, we will need to specify the pipe roughness terms, then solve by trial-and-error for the diameter required to carry the water at the desired flowrate. Page 31 of the EPA-NET manual suggests that the roughness height for cast iron is 0.85 millifeet.

As before the steps to model the situation are:

1. Start EPA-NET
2. Set defaults
3. Select the reservoir tool. Put two reservoirs on the map.
4. Select the node tool, put a node on the map. **EPA NET needs one node!**
5. Select the link (pipe) tool, connect the two reservoirs to the node. One link is the 2 mile pipe, the other is a short large diameter pipe (negligible head loss).
6. Set the total head each reservoir.
7. Set the pipe length and roughness height in the 2 mile pipe.
8. Guess a diameter.
9. Save the input file.
10. Run the program. Query the pipe and find the computed flow. If the flow is too large reduce the pipe diameter, if too small increase the pipe diameter. Stop when within a few percent of the desired flow rate. Use commercially available diameters in the trial-and-error process, so exact match is not anticipated.

Figure 10 is a screen capture after the model is built and some trial-and-error diameter selection. Of importance is the node and the "short pipe" that connects the second reser-

voir. By changing the diameter (inches) in the dialog box and re-running the program we can find a solution (diameter) that produces 10 cfs in the system for the given elevation differences.

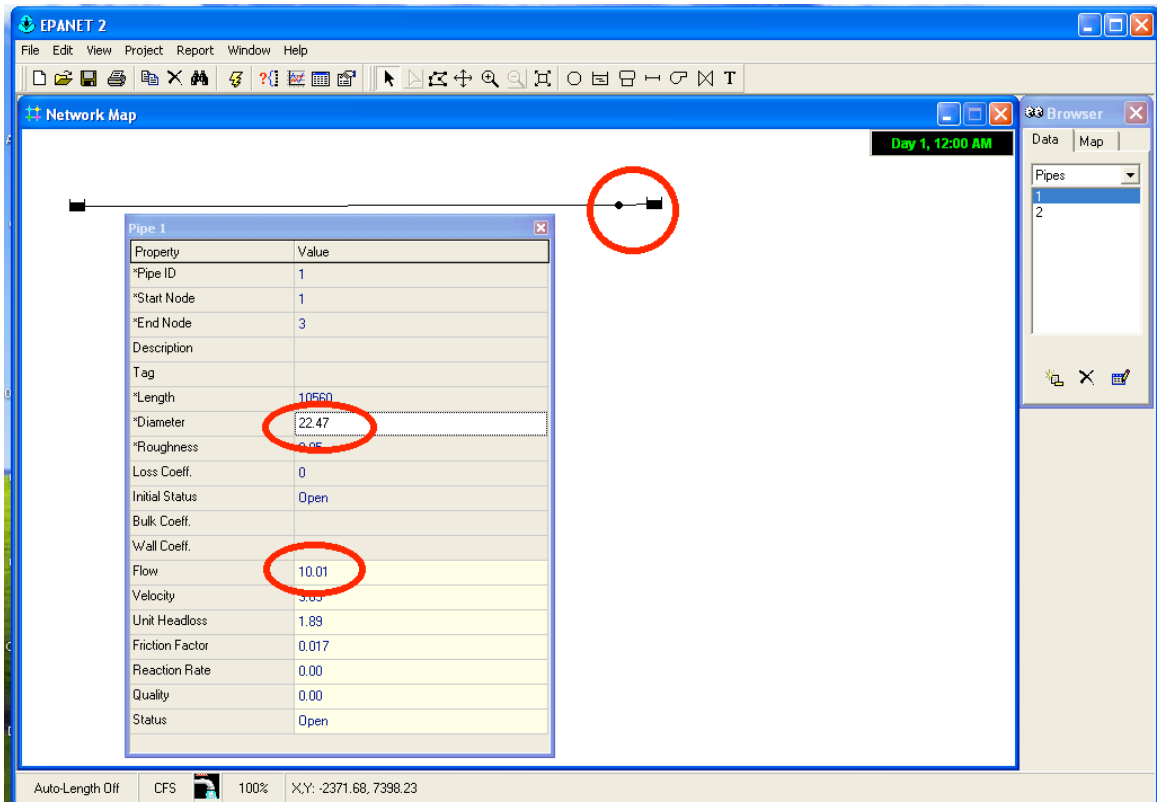

Figure 10: Solution dialog box for the pipe for Example 2

We would conclude from this use of EPA-NET that a 22.75 inch ID cast iron pipe would convey 10 cfs between the two reservoirs. Compare this solution to the "by-hand" soluton to see if they are close.

1.3.4 Example 3: Three-Reservoir-Problem

This example repeats another prior problem, but introduces the concept of a basemap (image) to help draw the network. First the problem statement

> Reservoirs A, B, and C are connected as shown[2] in Figure 11. The water elevations in reservoirs A, B, and C are 100 m, 80 m, and 60 m. The three pipes connecting the reservoirs meet at junction J, with pipe AJ being 900 m long, BJ

[2]This problem is identical to Chin Problem 2.30, Pg. 92

being 800 m long, and CJ being 700 m long. The diameters of all the pipes are 850 mm. If all the pipes are ductile iron, and the water temperature is 293^{o}K, find the direction and magnitude of flow in each pipe.

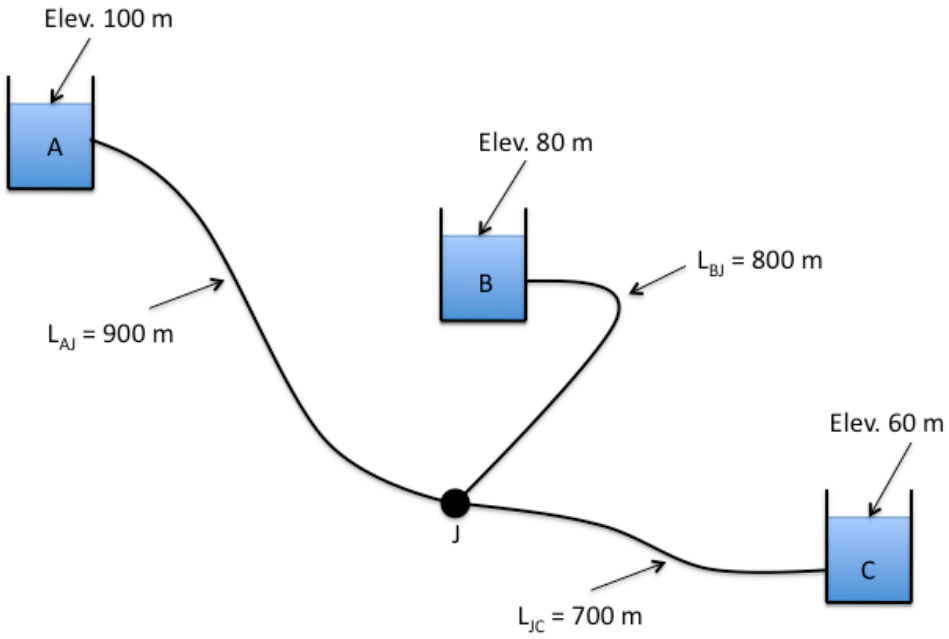

Figure 11: Three-Reservoir System Schematic

Here we will first convert the image into a bitmap (.bmp) file so EPA-NET can import the background image and we can use it to help draw the network. The remainder of the problem is reasonably simple and is an extension of the previous problem.

The steps to model the situation are:

1. Convert the image into a bitmap, place the bitmap into a directory where the model input file will be stored.
2. Start EPA-NET
3. Set defaults
4. Import the background.
5. Select the reservoir tool. Put three reservoirs on the map.
6. Select the node tool, put the node on the map.
7. Select the link (pipe) tool, connect the three reservoirs to the node.
8. Set the total head each reservoir.

9. Set the pipe length, roughness height, and diameter in each pipe.
10. Save the input file.
11. Run the program.

Figure 12 is the result of the above steps. In this case the default units were changed to LPS (liters per second). The roughness height is about 0.26 millimeters (if converted from the 0.85 millifeet unit).

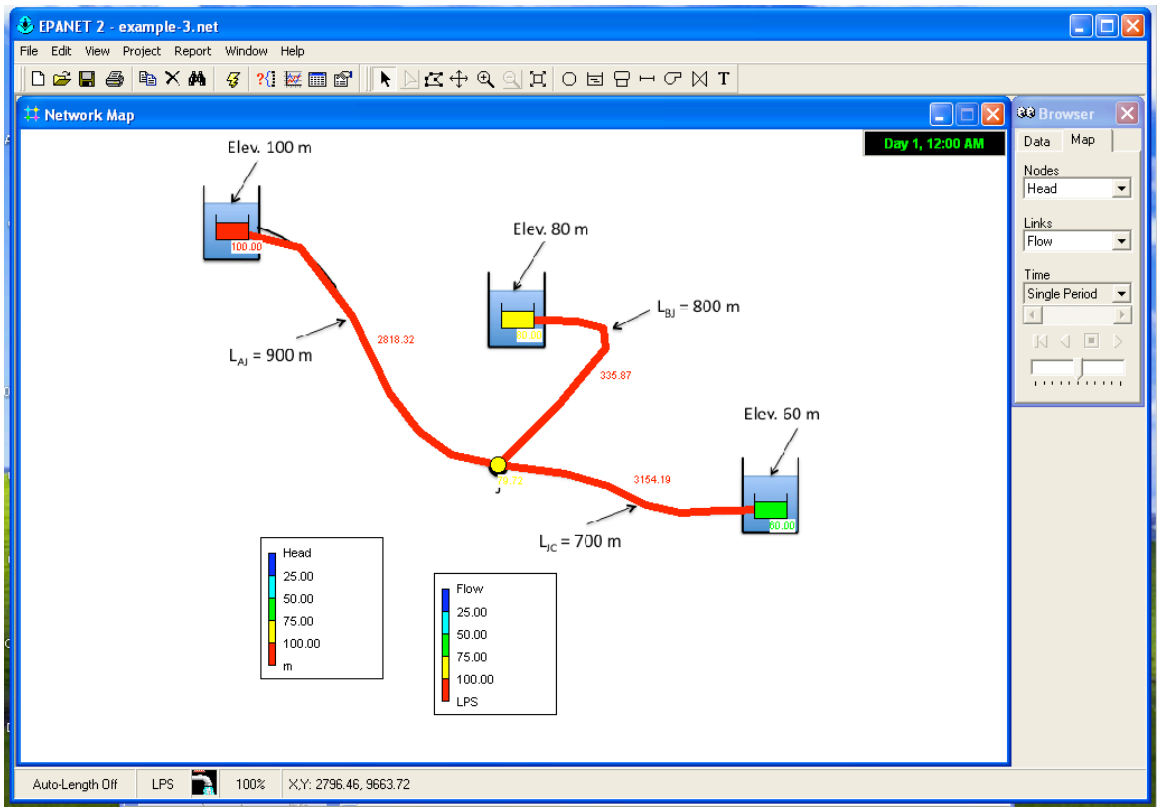

Figure 12: Solution for Example 3. The pipes were originally straight segments, but a drawing tool in EPA-NET is used to follow the shape of the underlying basemap. The training video shows the pipes as the straight lines. The flowrates are in liters-per-second, divide by 1000 to obtain cubic-meters-per-second.

1.3.5 Example 4: A Simple Network

Expanding the examples, we will next consider a looped network. As before we will use a prior exercise as the motivating example.

The water-supply network shown in Figure 13 has constant-head elevated storage tanks at A and C, with inflow and outflow at B and D. The network is on flat terrain with node elevations all equal to 50 meters[3]. If all pipes are ductile iron, compute the inflows/outflows to the storage tanks. Assume that flow in all pipes are fully turbulent.

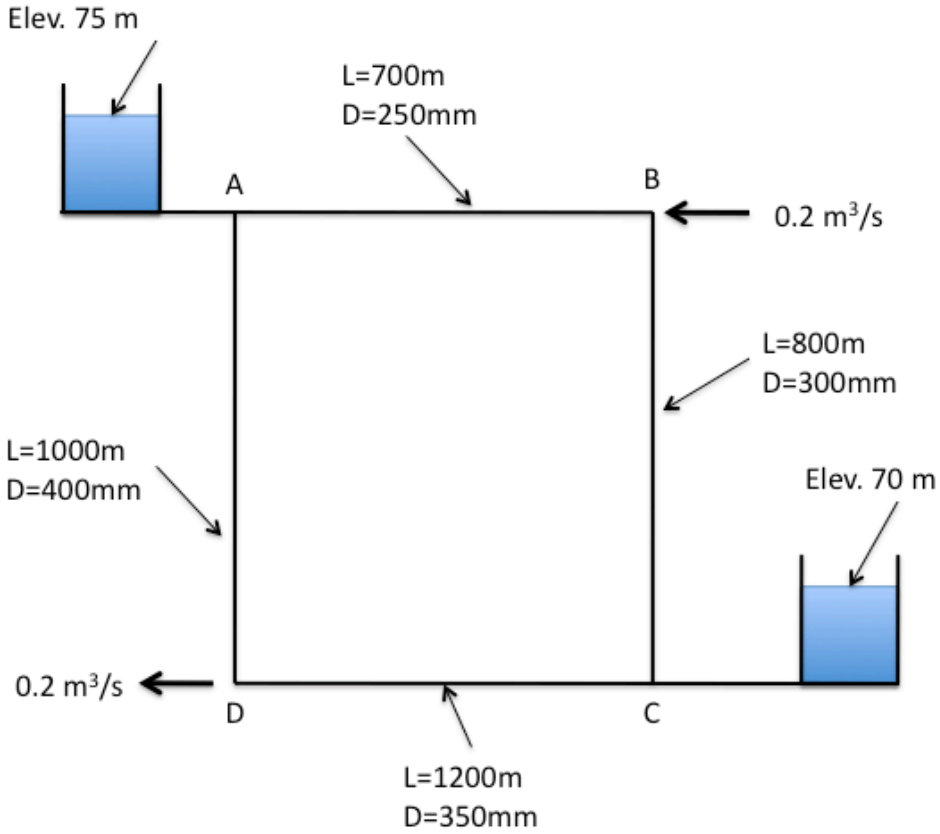

Figure 13: Two-Tank Distribution System Schematic

As before we will follow the modeling protocol but add demand at the nodes.

The steps to model the situation are:

1. Convert the image into a bitmap, place the bitmap into a directory where the model input file will be stored.
2. Start EPA-NET
3. Set defaults

[3]This problem is similar to Chin Problem 2.31, Pg. 92

4. Import the background.
5. Select the reservoir tool. Put two reservoirs on the map.
6. Select the node tool, put 4 nodes on the map.
7. Select the link (pipe) tool, connect the reservoirs to their nearest nodes. Connect the nodes to each other.
8. Set the total head each reservoir.
9. Set the pipe length, roughness height, and diameter in each pipe. The pipes that connect to the reservoirs should be set as short and large diameter, we want negligible head loss in these pipes so that the reservoir head represents the node heads at these locations.
10. Save the input file.
11. Run the program.

In this case the key issues are the units (liters per second) and roughness height (0.26 millimeters). Figure 14 is a screen capture of a completed model.

1.3.6 Summary — EPA-NET Examples 1-4

These examples did not have pumps or valves and as such are comparatively simple, yet represent the kind of problems that EPA-NET can model. Videos of the four examples are available on the server. To view these videos the reader will need the Apple Quick Time viewer (available for free from Apple). The WIndows Media Viewer usually can show the movies, but if not download the Apple Viewer and proceed. These videos have voice-over, so if you don't have speakers, you wont be able to hear the voice over.

1.4 EPA-NET Modeling by Example: Pumps

The next example illustrates how to model a pump in EPA-NET. A pump is a special "link" in EPA-NET. This link causes a negative head loss (adds head) according to a pump curve. In addition to a pump curve there are three other ways to model added head — these are discussed in the user manual and are left for the reader to explore on their own.

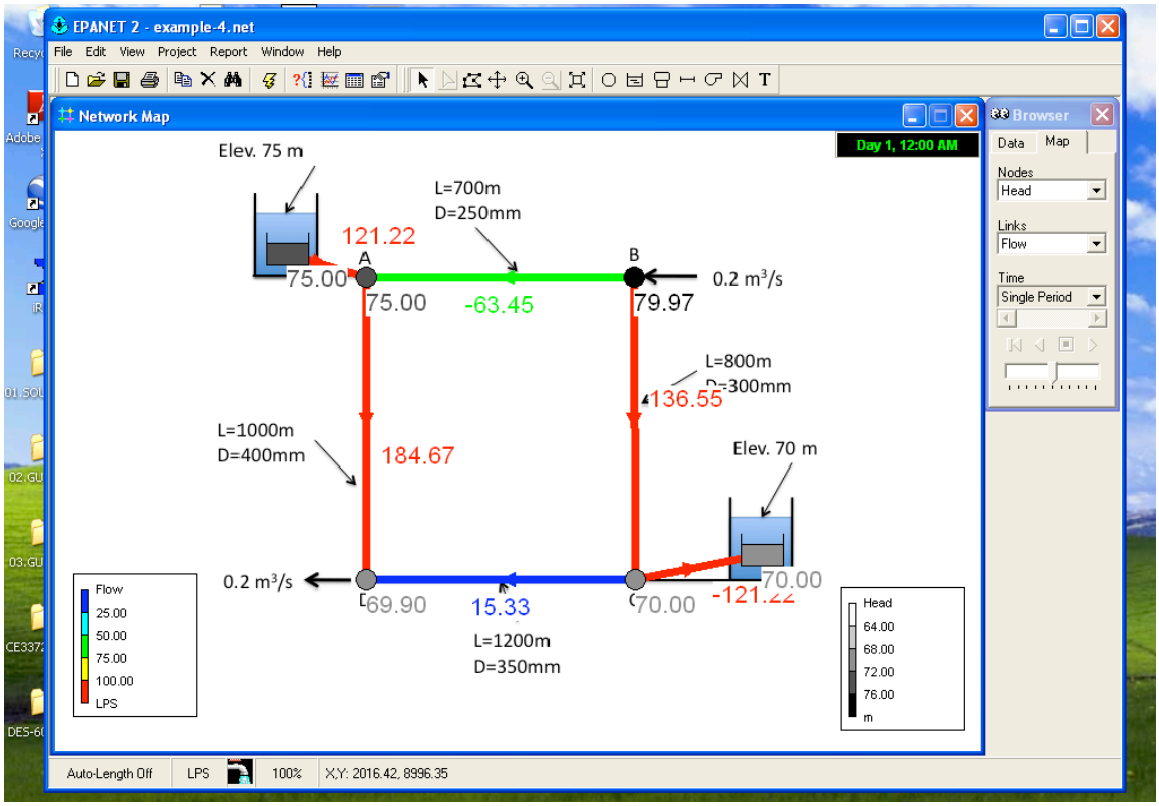

Figure 14: Solution for Example 4. The flowrates are in liters-per-second, divide by 1000 to obtain cubic-meters-per-second.

1.4.1 Example 5: Pumping Water Uphill

Figure 15 is a conceptual model of a pump lifting water through a 100 mm diameter, 100 meter long, ductile iron pipe from a lower to an upper reservoir. The suction side of the pump is a 100 mm diameter, 4-meter long ductile iron pipe. The difference in reservoir free-surface elevations is 10 meters. The pump performance curve is given as

$$h_p = 15 - 0.1Q^2 \tag{1}$$

where the added head is in meters and the flow rate is in liters per second (Lps). The analysis goal is to estimate the flow rate in the system.

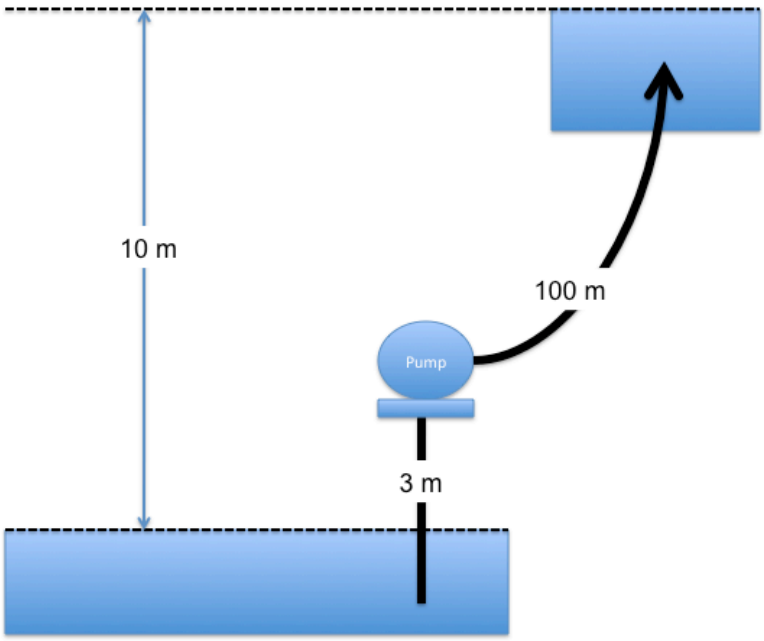

Figure 15: Example 5 conceptual model. The pipes are 100 mm ductile iron.

To model this situation, the engineer follows the modeling protocol already outlined, only adding the special link.

1. Convert the image into a bitmap, place the bitmap into a directory where the model input file will be stored.
2. Start EPA-NET
3. Set defaults (hydraulics = D-W, units = LPS)
4. Import the background.

5. Select the reservoir tool. Put two reservoirs on the map.
6. Select the node tool, put 2 nodes on the map, these represent the suction and discharge side of the pump.
7. Select the link (pipe) tool, connect the reservoirs to their nearest nodes.
8. Select the pump tool.
9. Connect the nodes to each other using the pump link.
10. Set the total head each reservoir.
11. Set the pipe length, roughness height, and diameter in each pipe.
12. On the Data menu, select Curves. Here is where we create the pump curve. This problem gives the curve as an equation, we will need three points to define the curve. Shutoff ($Q = 0$), and simple to compute points make the most sense.
13. Save the input file.
14. Run the program.

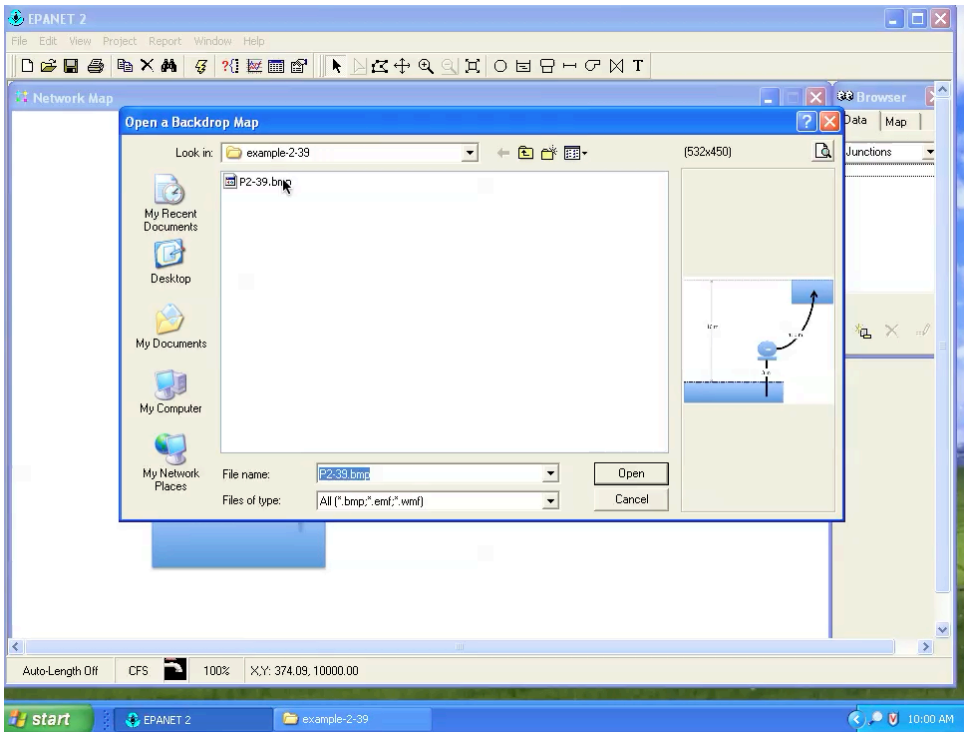

Figure 16: Example 5 select the background drawing (BMP file)

Figure 16 is a screen capture of loading the background image. After the image is loaded,

we can then build the hydraulic model. The next step is to place the reservoirs.

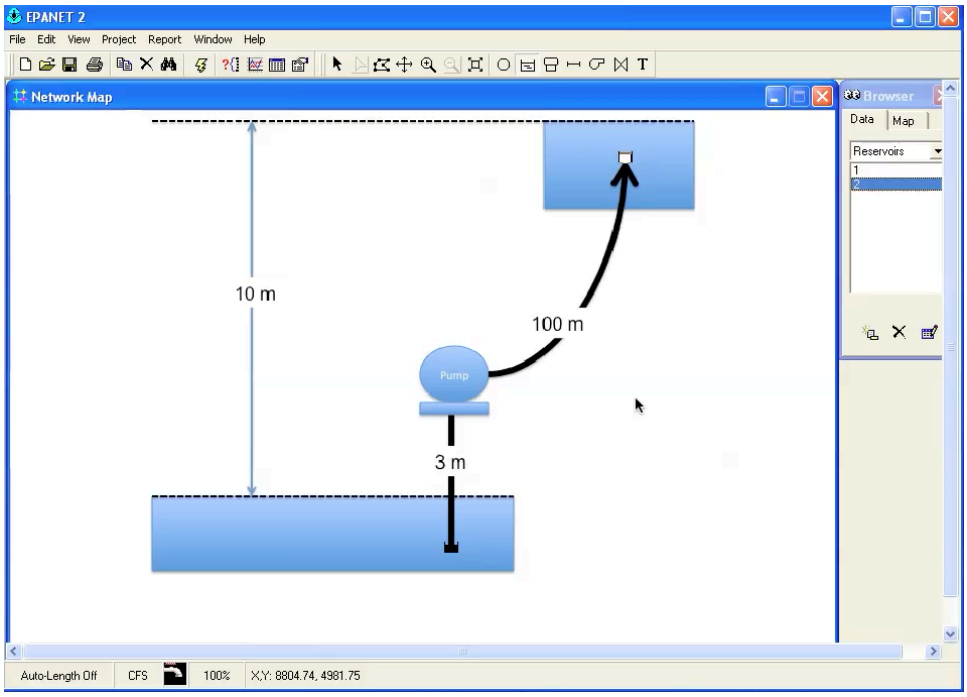

Figure 17: Example 5 place the lower and upper reservoir

Figure 17 is a screen capture of the reservoirs after they have been placed. The upper reservoir will be assigned a total head 10 meters larger than the lower reservoir — a reasonable conceptual model is to use the lower reservoir as the datum.

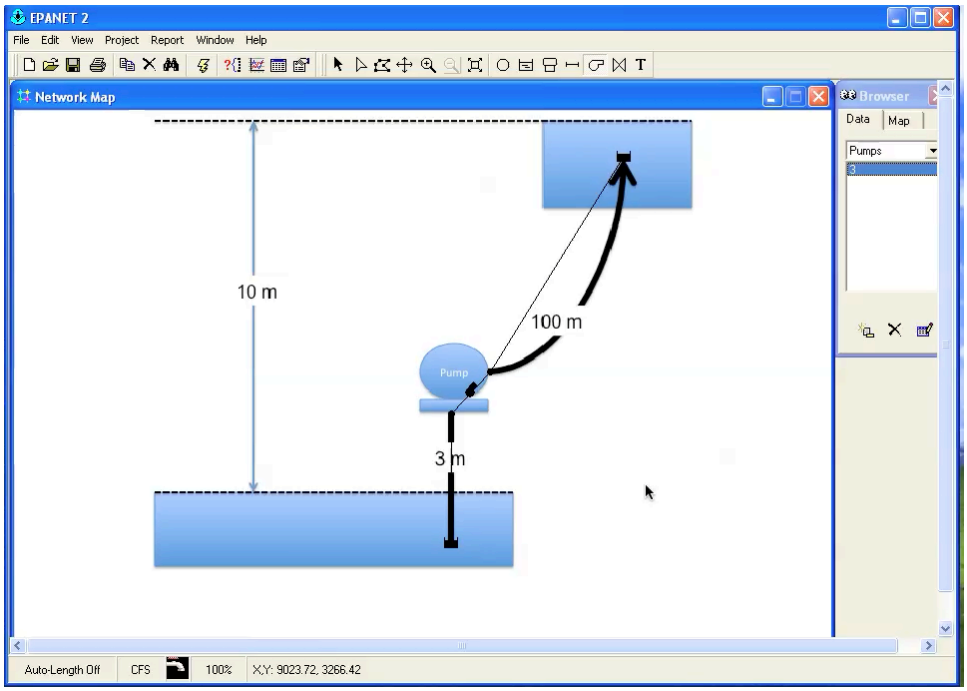

Figure 18: Example 5 place the nodes, pipes, and the pump link.

Figure 18 is a screen capture of model just after the pump is added. The next steps are to set the pipe lengths (not shown) and the reservoir elevations (not shown). Finally, the engineer must specify the pump curve.

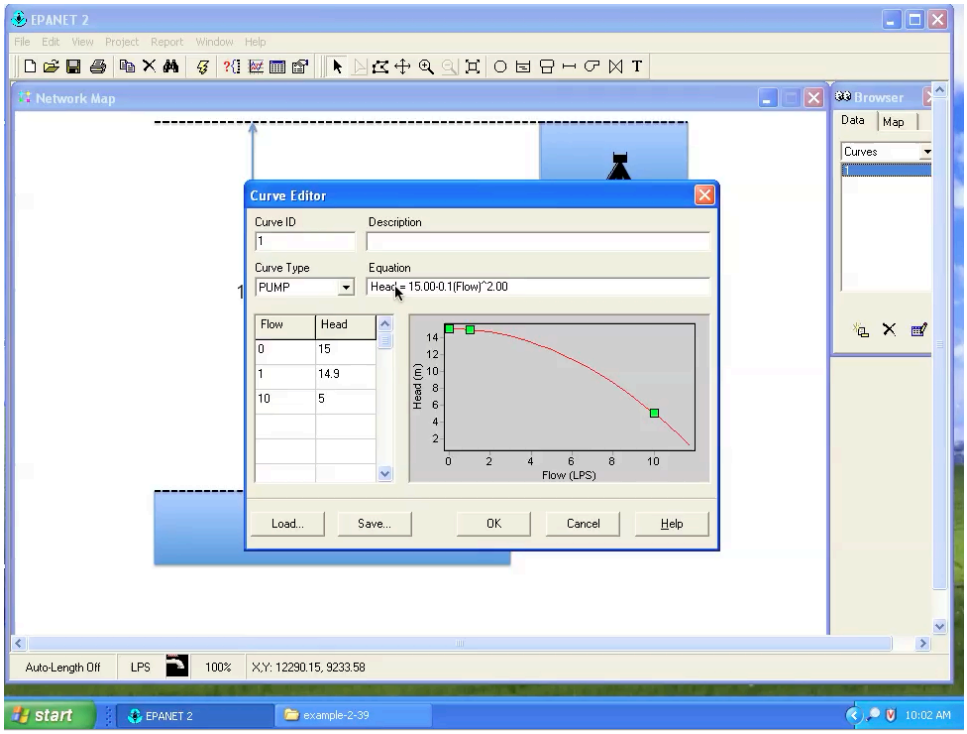

Figure 19: Example 5 pump curve entry dialog box. Three points are entered and the curve equation is created by the program.

Figure 19 is a screen capture of the pump curve data entry dialog box. Three points on the curve were selected and entered into the tabular entry area on the left of the dialog box, then the curve is created by the program. The equation created by the program is the same as that of the problem – hence we have the anticipated pump curve.

Next the engineer associates the pump curve with the pump as shown in Figure 20.

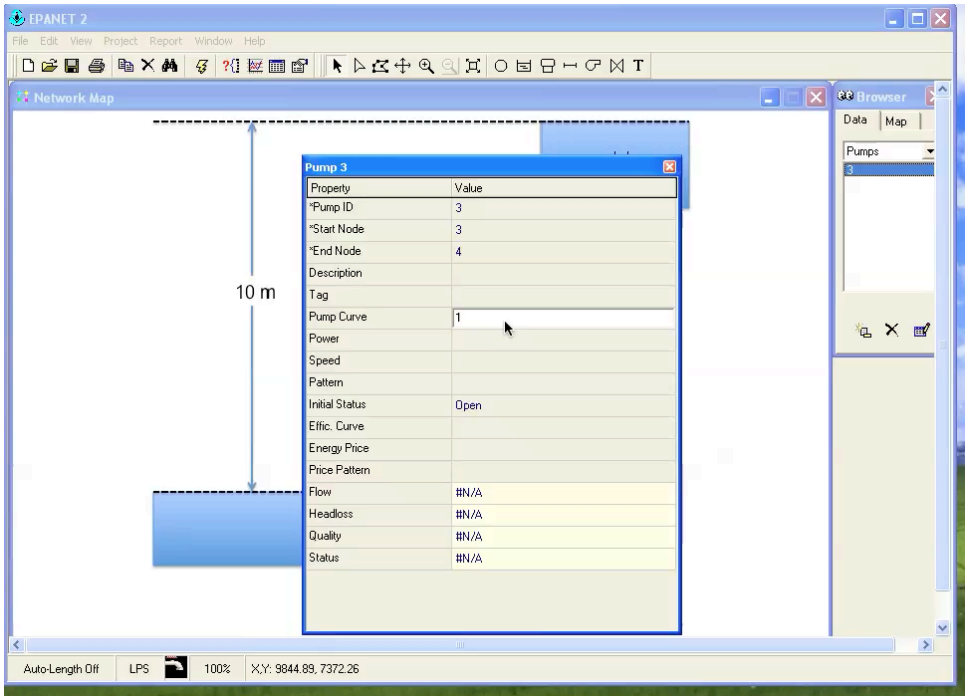

Figure 20: Setting the pump curve.

Upon completion of this step, the program is run to estimate the flow rate in the system.

1.5 EPA-NET Modeling by Example: Valves

EPA-NET models are comprised of nodes, links,and reservoirs. Pumps are treated as special links (that add head). Valves are also treated as special links depending on the valve types. All models must have a reservoir (or storage tank). The next example presents an analysis for a system where a valve is used to maintain a set pressure.

1.5.1 Example 6: Gravity Supplied Water Distribution Network

Consider a hypothetical water distribution system for Eagle Pass, Texas. The real system takes water from the Rio Grande and lifts it into an at-grade storage reservoir. From there the water is more or less gravity driven to the customers. Figure 21 is a map (not to scale) of the elevations of demand nodes in the Eagle Pass system. Figure 22 is a map of the customer population that needs to be served by the system. Figure 23 is a map (not to scale) of the individual pipeline diameter for each pipe in the major distribution network. Figure 24 is a map (not to scale) of the individual pipeline lengths for each pipe in the major distribution network.

To analyze such a system one would take the following steps.

1. Estimate the average and peak node demands in cubic-feet-per-second for each node in the Eagle Pass system. Cite your source of data and provide representative computations for demand at each node.
2. Classify the system (i.e. branch, grid/loop, or hybrid).
3. Prepare a table of the demands for average daily, peak hourly, and peak day demand for eventual inclusion in an engineering report.
4. Prepare a table of the node elevations for each node in the Eagle Pass system.
5. Prepare a table of the pipe dimensions for each pipe in the current system. Include in this table, appropriate Hazen-Williams loss coefficients for the pipes, indicate likely pipe materials.
6. Locate the lowest pressure node. Is the lowest pressure above the minimum Texas pressure for a water distribution system?
7. Locate the maximum pressure in the system, is the pressure reasonable or too large for typical customer connections?
8. Suggest a system modification (bigger pipes, new pipe, etc.) that could satisfy the low pressure issue in the system. Demonstrate by modeling, that your suggested modification indeed meets minimum/maximum pressure requirements.

9. Employ extended period simulation (different demand patterns) to assess loading conditions on meeting pressure requirements.

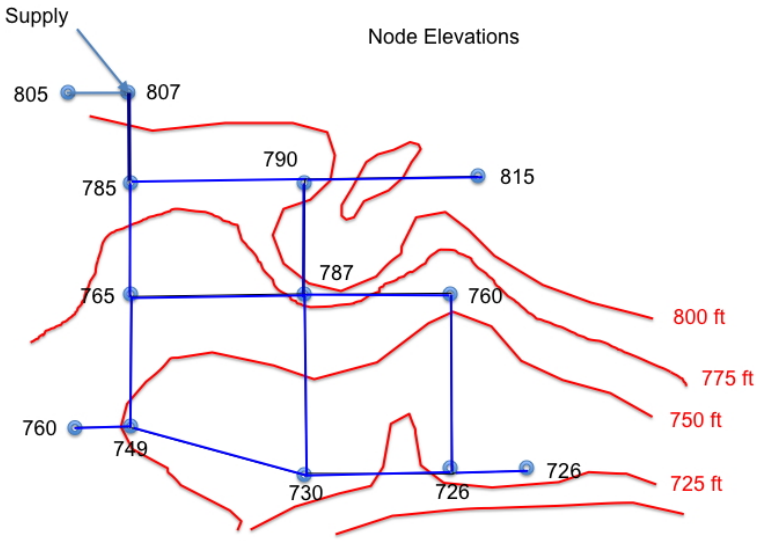

Figure 21: Eagle Pass water distribution node elevations. Elevations are feet above mean sea level.

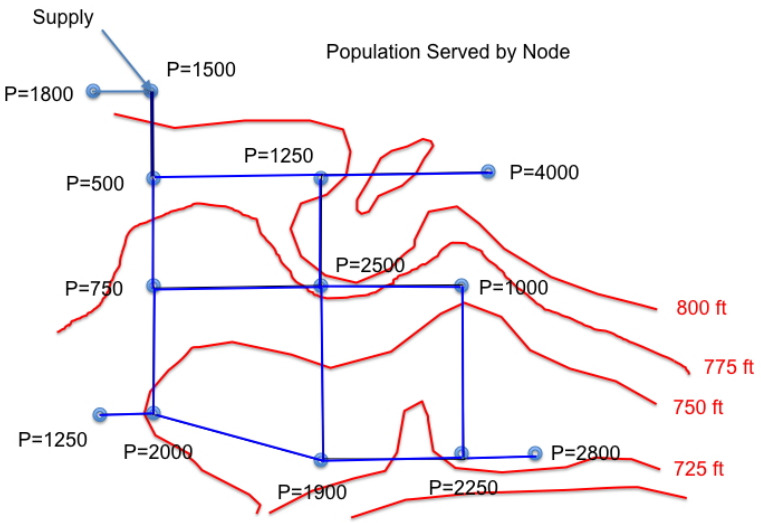

Figure 22: Eagle Pass water distribution node population served. Population is individuals served.

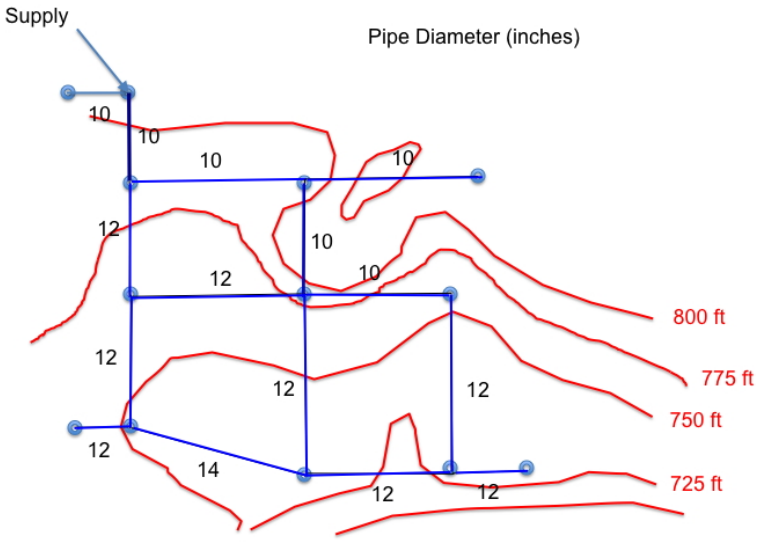

Figure 23: Eagle Pass water distribution pipe diameters. Diameter is in inches.

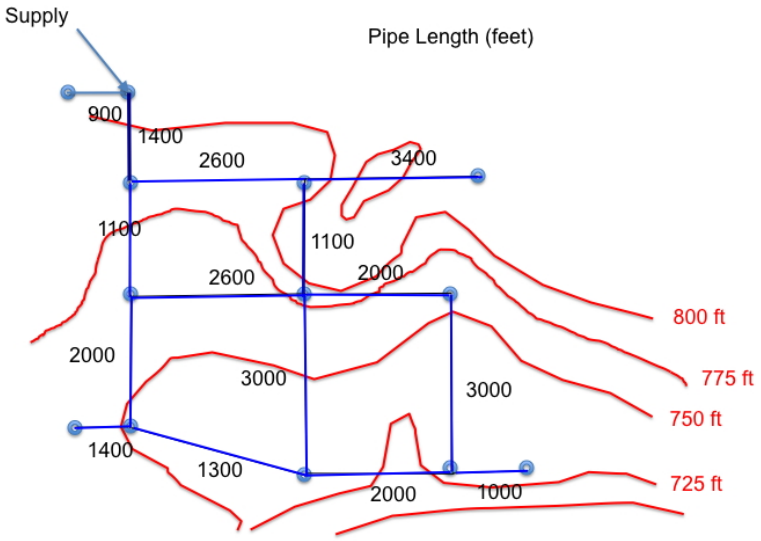

Figure 24: Eagle Pass water distribution pipe lengths. Length is in feet.

References

Chin, D. A. (2006). *Water-Resources Engineering*. Prentice Hall.

Gironas, J., L. A. Roesner, and J. Davis (2009). Storm Water Management Model applications manual. Technical Report EPA/600/R-09/077, U.S. Environmental Protection Agency, National Risk Management Research Laboratory Cincinnati, OH 45268.

NCEES (2008). *Fundamentals of Engineering Supplied Reference Handbook* (8th ed.). 280 Seneca Creek Road, Clemson, SC 29631: National Council of Examiners for Engineering and Surveying ISBN 978-1-932613-37-7.

Rossman, L. (2000). EPANET 2 users manual. Technical Report EPA/600/R-00/057, U.S. Environmental Protection Agency, National Risk Management Research Laboratory Cincinnati, OH 45268.

Rossman, L. (2009). Storm Water Management Model user's manual version 5.0. Technical Report EPA/600/R-05/040, U.S. Environmental Protection Agency, National Risk Management Research Laboratory Cincinnati, OH 45268.